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Collaboration through Digital Integration – An Overview of IT-OT-Integration Use-Cases and Requirements

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Abstract. Digitalization and Industry 4.0 continue to shape our industrial environment and collaboration. For many enterprises, a key challenge in moving forward in this matter is the integration of their shop-floor systems (hard- and software) with their office-floor systems to harvest the full potential of industry 4.0. A multitude of different technologies and respective use-cases available on the market leave many companies startled. This paper presents a set of use-cases for IT-OT-Integration to bring transparency into a company's digital transformation. Additionally, a technical requirements profile for integrating IT- and OT-Systems based on the use cases is presented. Both, use-cases and their requirements, guide companies in selecting the digitalization measures that fit their current situation and help in identifying technical challenges that need to be addressed in the transformation process.

Keywords: Industry 4.0, IT-OT-Integration, Digitalization

1 Introduction

Industry 4.0 together with digital transformation pose great innovation opportunities for many different industries and enterprises [1]. A majority of Industry 4.0 use-cases require integrating shopfloor systems, so called OT systems, with an enterprise's office floor systems (IT systems) [2, 3]. Being a central component of Industry 4.0, the integration of IT and OT also becomes a main component for collaborative networks, enabling to harvest their full potential [4].

However, realizing IT-OT-Integration is a main challenge for companies, especially for the limited budgets of SMEs [5–7]. Furthermore most enterprises' IT-OT-Landscape, meaning the existing IT-Systems, OT-Systems and interfaces, are very heterogeneous and companies are lacking transparency [8]. In addition, suitable methods for approaching a structured IT-OT-Integration process are missing [9, 10].

To address the issue the authors have developed a systematic approach for IT-OT-Integration based on the as-is assessment of an IT-OT-Landscape as well as a selection of Industry 4.0 utility potentials. Thus, combining a company's digitalization goals with the as is assessment of its infrastructure.

After a brief introduction into IT-OT-Integration and utility potentials, this paper presents an overview of industry 4.0 (utility) potentials forming the base for a structured IT-OT-Integration process. Next to that, an IT-OT-Integration profile prototype for assessing the status-quo of an IT-OT-Landscape as well as the matching process with the utility potentials is presented.

2 Developed IT-OT-Integration Methodology

To tackle the challenges of IT-OT-Integration, both the potential digitalization use-cases that are of relevance for a company's digital transformation as well as the existing IT-OT-Landscape need to be considered. This ensures the alignment of a company's strategic goals with its current situation. *IT-OT-Integration* refers to the interconnection of IT- and OT-Systems [10, 11]. The term, *IT-System* refers to the office floor systems of an enterprise such as: ERP (Enterprise Resource Planning) or Customer Relationship Management (CRM) [10, 12]. *OT-System* refers to the shop floor systems such as machines, scales, scanners and sensors, but also the software included for controlling them, such as MES (Manufacturing Execution System) [10, 12]. For structural reasons, MES is considered as an IT-System in terms of the methodology presented in this paper. In their previous work the authors presented a methodology for strategically selecting different digitalization measures [10]. Based on this work, this paper presents the next building blocks within the developed general IT-OT-Integration process. Fig. 1 gives an overview of this process.

In the beginning, potential digitalization measures, the so called utility potentials, are selected. In this paper, the term utility potential is used to describe business benefits (utility) in combination with their digitalization measure (potential) [10]. The selection process is covered in detail in [10]. In section 3 the authors present a list of predefined utility potentials for industrial application, also providing orientation in the process of the digital transformation.

After that, a company's or a certain environment's (such as a disctinct manufacturing line) IT-OT-Landscape is assessed. The methodology uses a morphological box as profile for assessing the as is status of the IT-OT-Landscape. For every system that is part of the assessment a profile is filled and stored for later assessment. Section 4 of this paper gives a detailed description of the assessment profile.

Step three uses the same profile for the matching process. In that process, the profiles from the assessment are compared with the profiles filled with the requirements of the utility potentials, revealing, which of the potentials can be easily fulfilled and which require further integration effort.

Finally, the matching results are combined with a set of action recommendations for starting the integration process. From there on, a company can take individual steps in realizing their IT-OT-Integration potentials.

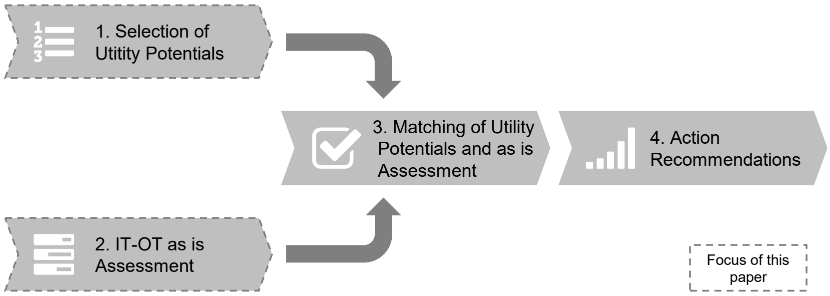

Fig. 1. Overview of developed methodology

3 Industry 4.0 Utility Potentials

The presented list of Industry 4.0 utility potentials was developed within a research project which forms the basis for this research. The potentials are derived from both literature research as well as expert interviews and were verified with the members of the user committee of the research project. The main literature sources include [13–18]. The expert interviews yielded individually applicable use cases and their respective analysis in the context of utility potentials.

Utility potentials map to general benefits to be achieved in production, consisting of cost reduction, optimization of process time, enhancement of the product's quality and flexibility of production. They describe specific measures that are classifiable into the categories *promotion of transparency*, *decision support* and *active production adaption* (compare Table 1).

Table 1: List of Utility Potentials clustered into three categories

Promotion of Transparency	Digital Order Tracking
	Digital Worker Guidance (e.g. AR)
	Realization of a Digital Twin
	Realization of a Digital Shadow
	Digital Capture of Lead Time
	Realization of Condition Monitoring
	Automatic Process Quality Documentation
	Automatic Collection of Production KPI
	Data-based Derivation of actual Process Cost
	Order Status Transparency in Production
Decision Support	Predictive Maintenance
	Dynamic Pricing in Production
	Realization of a Production's Digital Show
	Automatic Quality Evaluation with Data Analytics / Machine Learning
Active Production Adaption	Reduction of Machine Downtime
	Production Process Optimization with Data Analytics / Machine Learning
	Optimization of Process Duration
	Active Energy Management using Data Analytics
	Adaptive Production Adjustment for Errors and Downtimes
	Automatic Machine Configuration based on the Order

The category *promotion of transparency* includes measures, in which data is collected to visualize operational conditions and further allow the analysis of simple causalities between process parameters and the product.

The *support of decision-making* builds on top of the enhanced transparency, by utilizing further data sources and active analysis to generate insights into production, forecasts and detect necessary actions.

The final category, *active production adaption*, usually adds onto the previous decision-making, by actively reacting to available information. The adaption takes the form of automatic decision-making and regulation of the process or system. In contrast to the perceived complexity, the measures implementing active adaption can also represent a simple functionality such as the automatic configuration of machines in response to an order command.

The identified utility potentials were each analyzed to determine the required functionalities and architecture within the construct of IT components, OT components and their corresponding connectivity. This analysis was supported by modelling the expected data flow, to demonstrate the individually required system in a network of general IT and OT components, as shown in Fig. 2. The model allowed an intuitive translation of the utility potentials into the proposed IT-OT-Integration Profile.

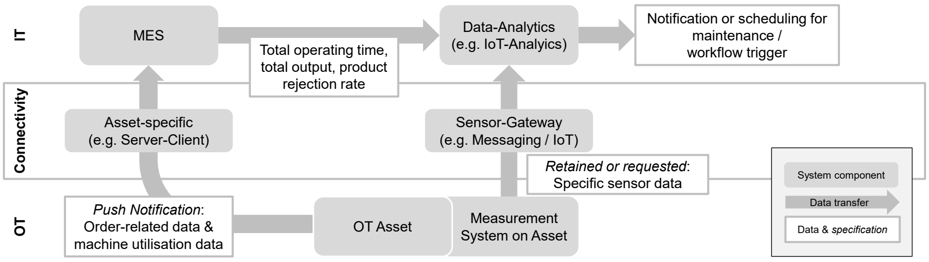

Fig. 2: Requirements on the IT-OT-architecture for the utility potential "Predictive Maintenance"

4 Prototype of IT-OT-Integration Profile

The matching of a production's IT-OT as is assessment to the determined utility potentials requires a unified IT-OT-integration profile. The goal is to establish a generalized framework that allows a representation of both actual, specific production systems/architectures and the diffuse requirements of a utility potential, without dictating definitive solutions and technologies. Furthermore, the as is and the proposed architecture need to be comparable to derive technical measures that are required to fulfill the utility potentials requirements.

The proposed profile divides the underlying architecture into OT-components, IT-components and interfaces, whereas each specific component in an actual production is represented as its own instance within either of these sections. An ERP-System for example is represented as an IT-component, a production machine as an OT-component and their interconnection as an interface component. The whole structure including the list of options for the components' attributes is shown in Table 2 (table is split into three segments due to print formatting). The structure and attributes were derived and developed in expert interviews. The profiles are used to capture the specification of a component, by selecting relevant options of a given attribute.

Table 2: Unified OT-, Interface- and IT-profiles with corresponding attributes and their respective list of options (gray attributes are not defined by utility potentials)

OT				
Attribute	**Value Options**			
Exchanged Data	Process data	Order data	Environment data	
Push-Capabilities (Data out)	Real-time	< once per day	< once per hour	
	Events only	None		
Pull-Capabilities (Data out)	On request / polling	Short-time buffered		
	Real-time	Historical	None	
Access Permissions	Read	Write	Execute	None
Hardware Interface	None	Analog / parallel IO	Basic serial IO	
	RJ45	Profibus	<custom>	
Avl. Communication Protocols	None	HTTP(S)	MQTT	
	OPC-UA	Profibus	<custom>	
System Modifiability	Proprietary	Proprietary, but unlockable	Open	

IT				
Attribute	**Value Options**			
Required Data	Process data	Order data	Environment data	
Provided Data	Process data	Order data	Environment data	
Avl. Communication Protocols	None	HTTP(S)	MQTT	
	OPC-UA	Profibus	<custom>	
Type	ERP	MES	IoT-Platform	
	Database	Dashboard	PLM	<custom>
Functionality (data-)	Acquisition (from OT)	Acquisition (from IT/user)		
	Preprocessing	Enrichment	Virtualization	
	Distribution	Storage	Analytics	
	Delivery	Visualization		
Data Analytics	None	Target vs. actual		
	Generate visibility	Transparency & diagnostics		
	Forecast	Adaption & decision automation		

Interface			
Attribute	**Value Options**		
Communication Protocol	HTTP(S)	MQTT	OPC-UA
	Profibus		<custom>
Configurability	Proprietary		Programmable
	Static configuration		Low-code / No-code
Roles of the IT System	Server		Client
Transfer Format	Stream	Database	File
	Request/transaction	Manual	<custom>
Transfer Volume	Low	Medium	High
Connected Systems	<OT references>		<IT references>

The OT profile comprises the general type of exchanged data (namely order data, process data and environment data), the technical nature of the interfaces, regarding physical ports and data protocols, and the capabilities of the data transfer. It represents the digital capabilities and functionalities of the OT system under consideration, including all its applied additions e.g. sensors and retrofits.

The IT profile comprises the type of IT system at hand, the implemented communication protocols, the exchanged data (similarly to the OT system) and the general functionality extended by eventual data analytics capabilities. The exchanged data is further divided into required and provided data.

Interfaces between each one or more IT and OT systems are defined by its communication protocol, its configurability and the characteristic of the data transfer regarding directionality, format and bandwidth. Additionally, the interface references the IT and OT systems it is connecting. Multiple interfaces of similar nature, e.g. a one-to-many connection, can easily be summarized within one interface instance by referencing multiple IT or OT components.

Table 3: Attribute-wise matching of as-is assessment (crosses) and chosen utility potential (circles) in an exemplary OT profile

OT				
Exchanged Data	Process data		⊗ Order data	○ Environment data
→ Environment data ist not handled: Sensor are to be fitted				
Push-Capabilities (Data out)	Real-time		○ < once per hour	× < once per day
	Events only		None	
→ Push rate is too low: Proprietary modifialbility dictates Retrofit				
Pull-Capabilities (Data out)	On request / polling		× Short-time buffered	
	Real-time		Historical	○ None
→ No Requirements by utility potential				
Access Permissions	⊗ Read	× Write	× Execute	None
→ Requirements are met				

The generalized requirements of a utility potential are summarized in exactly three components, one of each type. The specific attributes of each component are disregarded (marked in gray), as they dictate a technical solution. This approach was chosen to allow for a general evaluation of multiple and vastly different specific production architectures. In fact, disregarded attributes only serve to evaluate possible interconnections of components and eventually the difficulty of achieving such. The matching of a production's as-is assessment to the utility potentials is demonstrated in Table 3.

By assessing an attribute's delta to the desired utility potential and evaluating its difficulty of solving the delta, using the specific attributes (in grey), an appropriate measure can be derived. Similarly the interfaces, the IT-systems and the interconnectivity is handled. The overall assessment then allows for an identification of critical measures and their respective difficulties, e.g., solvable by using Retrofits, to achieve the utility potential.

5 Outlook & Conclusion

Mastering the IT-OT-Integration process is a challenge for many companies, especially SMEs. Therefore, this paper presents a set of utility potentials as well as an IT-OT-Integration profile to structure and assist the integration process.

In the beginning, the developed IT-OT-Integration approach is presented and put into the context of previous research activities. Afterwards a set of utility potentials to select in the beginning of an IT-OT-Integration project is shown. Subsequently, an Integration profile with the categories IT, OT and Interface to assist the structured as is assessment of an IT-OT-Landscape is introduced. Finally, the matching process between the selected utility potentials and the as is assessment of the IT-OT-Landscape is explained.

Future research will further explore the presented approach to prove its validity. Additionally, the methodology will be assisted by a web-based application to facilitate the access to IT-OT self-assessments.

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